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COMMUNICATION SYSTEM AND METHOD FOR COMMUNICATION

Field of the Invention

This invention relates to a communication system comprising at least one central and a number of remote units and employing a shared frequency band.

Background of the Invention

Communication systems including at least one central and a number of remote units typically use separate portions of the frequency spectrum or frequency bands for the uplink (remote units transmitting to the central station) and the downlink (the central station transmitting to the remote units). A typical example of such a system is the Global System for Mobile telecommunication (GSM) where the uplink and downlink are transmitted in different frequency bands 45 MHz apart.

A major disadvantage with separate frequency bands is the inflexibility caused by the need for a fixed allocation of total spectrum used for the uplink and for the downlink.
In many systems the total traffic distribution between the uplink and downlink vary significantly with time. A fixed allocation of spectrum for each direction therefore requires dimensioning for worst case scenarios in the up- and downlink independently whereas the total traffic may be significantly less than the sum of the individual worst case situations. A significant improvement can be obtained if the spectrum can be dynamically allocated between the uplink and downlink.

As an example it has been identified that the variation in time of the traffic distribution between the uplink and downlink in the future Universal Mobile Telecommunication System (UMTS) will be very large. As a result it has been specified that it will be advantageous if the UMTS air interface will be able to share spectrum dynamically between uplink and downlink.

Separation of different radio signals in communication systems is achieved by separation in either time, frequency, code or a combination thereof. However, when sharing the same spectrum between uplink and downlink the separation becomes increasingly difficult as the power variation between desired and undesired signals can be extremely large. A typical example is the situation where a remote unit is located on the edge of the coverage area and therefore receives a very weak signal from the central station. At the same time a nearby remote unit may transmit to the central station using high power as it is also close to the edge of the coverage area thereby causing a very strong interfering signal.

If the signals are separated in time, such as in a Time Division Duplex (TDD) scheme the interference can be constrained to time intervals not used by the current remote unit and separation can therefore be very effective. However, the requirement for guard time between transmission and reception makes a time division scheme impractical for anything beyond very small cells (typically less than one kilometre). Division in frequency requires a very large attenuation of the unwanted signal due to the high power variation between the signals and this imposes very strict requirements on the filters resulting in large and expensive filters. Similarly, division in code will also require a very large attenuation of the unwanted signal due to the high power variation and this will result in the need for very long codes which complicates the receiver design significantly.

A new invention is therefore desired for facilitating the sharing of spectrum between the uplink and downlink.

Summary of the Invention

According to the present invention, there is provided a communication system including a first central station, a plurality of remote units, and a frequency spectrum for providing communication services to the plurality of remote units, the communication system comprising: means for transmitting between the first central station and a first remote unit in a first portion of the frequency spectrum in a first direction using a first transmission scheme;

and the communication system being characterised by comprising: means for transmitting simultaneously between the first central station and a second remote unit in the first portion of the frequency spectrum in a second direction using a second transmission scheme.

The different transmission schemes are preferably characterised by one having the signal energy spread in preferably both the time and frequency domain whereas the other transmission scheme having signal energy concentrated in preferably both the frequency and time domain.

According to one feature of the invention the spread energy signals can be spread un-evenly thereby concentrating signal energy in frequencies with the minimum cross-directional interference. According to another feature of the invention, remote units may be allocated spectrum so that units uplinking and downlinking in the shared portion of the frequency spectrum are separated geographically thereby increasing the minimum coupling loss between the units and thus minimising the interference.

According to a second aspect of the invention there is provided a method for communication in a communication system including a first central station, a plurality of remote units, and a frequency spectrum for providing communication services to the plurality of remote units, the method comprising the steps of: transmitting between the first central station and a first remote unit in a first portion of the frequency spectrum in a first direction using a first transmission scheme; and the method being characterised by comprising the step of: transmitting simultaneously between the first central station and a second remote unit in the first portion of the frequency spectrum in a second direction using a second transmission scheme.

Brief Description of the Drawings

FIG. 1 is an illustration of a typical communication system to which this invention may apply.

FIG. 2 is an illustration of frequency band allocation for uplink and downlink traffic in a preferred embodiment.

FIG. 3 is an illustration of a preferred embodiment of a remote unit.

FIG. 4 is an illustration of an example of signal energies spread or concentrated according to the invention.

FIG. 5 is an illustration of an uneven spreading of signal energy applied to the spread energy signal.

FIG. 6 is an illustration of a preferred allocation of channels in the shared frequency band to remote units.

FIG. 7 is an illustration of a process flowchart of a preferred method of allocating channels to users.

Detailed Description of a Preferred Embodiment

According to the present invention, a communication system 100 allowing sharing of spectrum between the uplink and downlink is provided, the system comprising at least one central station and a plurality of remote units. FIG. 1 illustrates such a system where a central station 101 communicates with a number of remote units 103 over radio channels 105. Specifically, the communication system can be a cellular system where the central station covers users within a certain geographical area 107 whereas other geographical areas 109,111 are covered by other central stations 113,115. An example of such a system is the UMTS cellular system undergoing standardisation in the European Telecommunications Standards Institute.

According to the present invention at least a portion of the spectrum is allocated for simultaneous use in the uplink and downlink direction. A

preferred spectrum allocation 200 is shown in FIG. 2. A portion of the spectrum is allocated for uplink 201, another for downlink 205 and a third is shared between up- and downlink 203. It is preferred that call setup is performed using the separate up- and downlink portions of the frequency spectrum 201,205 as the interference in these bands are expected to be less than in the shared spectrum 203. The interference in the shared spectrum can be very severe in some situations for example if a remote unit using this band for uplink is very close to a remote unit using the same spectrum for downlink.

The principle of the current invention is to use a hybrid air interface at least in the shared portion of the frequency spectrum by employing different transmission schemes which cause the least cross-interference between the uplink and downlink. The preferred system will spread the signal energy in one direction as much as possible while concentrating the signal energy as much as possible in the other direction. The spreading of energy in one direction will preferably be in both the time and frequency domain and similarly the concentration of signal energy in the other direction will also preferably be in both the time and frequency domain.

A preferred implementation of a remote unit 103 is illustrated in FIG. 3. The remote unit 103 comprises an antenna 301 connected to a duplexer 311 which again is connected to a receiver unit 303 and transmitter unit 309. The receiver and transmitter units 303,309 are connected to a controller 305 which is connected to a user interface 307. The remote unit 103 thus provides means for transmission and reception of user data under the control of a controller 305. The transmitting unit 309 is able to transmit using a different transmission scheme than the receiving unit 303. For example according to the invention the transmitting unit 309 can employ a time continuous broadband signal whereas the receiving unit 303 can employ a time division narrow band signal. In addition the transmitter unit 309 and receiver unit 303 may be able to use a plurality of transmission schemes and operate in a plurality of different frequency bands. The central station 101 is similar to the remote units 103 but the transmission schemes available will typically be reciprocal to the remote units 103, so that the transmission schemes available to the receiving unit 303 in the remote unit 103 will be available in the transmitting unit 309 of the central station 101 and vice

versa. Which transmission scheme to use is determined in the controller 305 in the remote units 103, the central station 101 or may be distributed throughout the system. The details of receiver and transmitter design for various transmission schemes are well known in the art, and the skilled person may use any known method of transmitter or receiver design without detracting from the present invention.

A preferred energy distribution 400 is illustrated in FIG. 4 where a spread energy signal 401 and concentrated energy signals 403 are shown.

When considering the frequency domain the spread energy signal 401 corresponds to a broadband signal where the radio signal occupies a relatively high bandwidth but has relatively low spectral energy density. Preferably the signal is spread using a spread spectrum technique as is well known in the art. Other alternatives for spreading the signal include known techniques such as frequency hopping or increasing the bandwidth of the signal by introducing redundant data. An example of the latter is the use of Forward Error Correcting (FEC) codes which allows transmission at lower spectral power density and increased bandwidth. The concentrated energy signals corresponds to standard narrowband signals where no or limited frequency spreading is applied.

When considering the time domain, the spread energy signal corresponds to a signal of long duration in comparison to the transmissions of the concentrated energy signal, preferably it is a continuous signal. The concentrated energy signal corresponds to a signal which performs the transmissions in short bursts rather than continuous transmissions. These signals are for example used in TDMA communication systems. The spread energy signal is thus characterised by having a relatively low variation in transmitted power whereas the concentrated energy signal will have high peak power during transmission bursts.

When receiving the signals the high disparity between the two transmission formats will provide significant benefits in terms of reduction of the interference level, the possibility of using interference reduction receiver techniques and the possibility of using techniques minimising the impact of the given interference.

When receiving the concentrated energy signal such as a non-frequency spread TDMA signal, the interference energy from a possible nearby strong interferer will be spread in both time and frequency. The interference energy contained in the relevant time-slot and narrow frequency channel is therefore minimised. As an example, if a GSM speech call is considered a 200 kHz channel is used. Assuming an interfering signal is spread to 5 MHz (as is considered for UMTS), the interference power of this signal in the narrowband GSM channel will be reduced by 25 times i.e. by 14 dB. The reduction of interference power will substantially decrease the dynamic range requirement of the receiver. In addition the GSM TDMA signal has a duty cycle of 1/8 and the total reduction in interference energy is thus 200 times i.e. 23 dB.

When receiving the spread energy signal the concentrated energy signal can have a very high interference level but this will be concentrated preferably both in time and frequency. It is thus possible to remove this high interference by filtering using for example a notch filter. This will again remove a potentially very high interference level thereby significantly reducing the dynamic range requirements of the receiver. The filtering of the unwanted narrowband interferer will also remove a part of the wanted signal. However, as the filtering is concentrated to a narrow bandwidth and a short timeslot, this effect will be acceptable in most situations. The interferer will be constrained to a short time interval and extending the interleaving and FEC coding beyond this time interval will significantly reduce the amount of bit errors caused by the interferer. If the energy concentrated signal is a TDMA signal the interleaving and coding will preferably extend over an entire frame length

In accordance with the invention the interference levels can be further reduced by spreading the spread energy signal unevenly in frequency depending on the interference to and from remote units using the shared spectrum for communicating in the other direction. This is illustrated in FIG. 5 where an evenly spread signal 501, an unevenly spread signal 503 and narrowband signals 505 are shown, the spread signals representing communication in one direction and the narrowband signals representing communication in the other direction. By concentrating the spread signal

energy towards the spectrum not used by narrowband signals, the interference to and from these is reduced

As an example spreading codes used for current CDMA systems are optimised for a flat frequency response as this gives optimum performance for a pure CDMA system. However, in the proposed system there can be much higher interference in some frequency bands than in others and it is therefore preferred to use non-flat spreading codes which concentrate the CDMA signal energy towards frequencies with minimum interference. For example, if the narrowband interferers are allocated towards the higher frequencies, a spreading code concentrating energy towards lower frequencies can be used (ref. FIG. 5). Any other distribution is equally applicable to the current invention, for example allocating narrowband carriers periodically or towards the lower or middle part of the frequency bands in order to optimise the system for the given spectral shaping of the spread signal. The method can be used adaptively dependent on the number and level of narrowband interferers. The shaping of the spreading can either be obtained by changing the spreading code or by modifying the pulseshape of the spreading signal. If the spreading is done using frequency hopping, the effect can be obtained simply by increasing the concentration of hops to frequency bands with less interference.

Another aspect of the invention concerns the reduction of interference between remote units in the described communication system by allocation of channels in the shared portion of the frequency spectrum to remote units geographically separated. An example of the principle of allocation is illustrated in FIG. 6 which shows one central station 601, a plurality of remote units 603 and three areas 605, 607 and 609 dividing the remote units into groups depending on their distance to the central station 601. According to the invention calls can be set up using the dedicated portions of the frequency spectrum, and as desired calls can be allocated channels in the shared spectrum in such a way, that they use the shared spectrum for communication in one direction and the appropriate dedicated spectrum for communication in the other direction. The principle of allocation of the shared spectrum is that it is used in one direction by the remote units closest to the central station and in the reverse direction by the remote units furthest from the central station. With reference to the figure, remote units

603 in area 605 will thus be allocated for example downlink channels in the shared spectrum and uplink channels in the dedicated uplink frequency spectrum whereas the remote units in area 609 will be allocated uplink channels in the shared spectrum and downlink channels in the dedicated spectrum. The basic principle is thus to allocate channels so that remote units uplinking in the shared spectrum are kept as far as possible from the remote units downlinking. This maximises the minimum coupling loss between remote units sharing spectrum and thereby minimises interference.

FIG. 7 is an illustration of a process flowchart 700 of a preferred embodiment of this method. The method is preferably implemented in the controller of the central station 601 but may be implemented in the remote units 603 or distributed throughout the system.

The process starts in step 701 where the distance between the central station 601 and the remote unit 603 is estimated. The further the remote unit 603 is from the central station 601 the higher the propagation loss and the preferred method of estimating the distance is therefore from measurement of the received signal strength and knowledge of the transmitted power level, or simply from knowledge of the transmitted power level for a given transmission quality. However, other alternatives include measurement of transmission delay, such as timing advance for GSM systems, or using location information, such as information from Global Positioning System receivers included in the remote units as is envisaged for some future communication systems.

Step 703 follows from step 701 and consists in allocating radio channels in the shared portion of the frequency spectrum to the furthest of the remote units 603. The allocation is such that the remote units 603 are allocated channels in one direction in the appropriate non-shared spectrum and channels in the second direction in the shared spectrum.

Step 705 which follows from step 701 and may be independent of step 703 allocates channels to the closest remote units 603. The allocation is reciprocal to the allocation of channels to the furthest remote units in step 703. The remote units are thus allocated channels in the appropriate non-shared spectrum for communication in the direction in which the furthest

remote units 603 use the shared spectrum. The closest remote units 603 are furthermore allocated channels in the reverse direction in the shared frequency spectrum but utilising a different transmission scheme in accordance with the invention.

The invention thus provides a communication system or method of communication based on using different transmission schemes in the uplink and downlink direction. The use of two different transmission schemes allows for the uplink and downlink signals to have a large disparity and this enables the cross interference between these signals to be minimised. As a consequence the sharing of a portion of frequency spectrum for simultaneously communicating in both directions is substantially facilitated.